# Wireless Energy Meter with Home Automation

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**Abstract -** *The lack of credibility of data acquired through traditional means from a conventional metering system has reduced the efficacy of the energy management system. In this project we introduce a smart IoT based energy management system (EMS). This system provides flexibility to the consumers by offering the facility of remotely controlling their home appliances with Wireless Home Automation. The electricity consumption information is evaluated using Automatic Meter Reading technique. The energy consumed by individual devices is calculated via an android application based on their energy consumption per hour. The overall cost for the energy consumed is calculated automatically and then it is notified to the user within the android application. Effective use of NodeMCU (Node Micro-Controller Unit) which has functionality of both micro-controller and Wi-Fi modules. The energy consumption is monitored by the NodeMCU and is transmitted to the application using the Client-Server model. Consumers can observe real-time data on the application to gain a clear idea of electricity usage and can manage to use enough electricity for household appliances using technique of Demand Side Management. This system allows the effective energy consumption budget analysis. This system can be also integrated with the existing prepaid meters of the market, eradicating its major drawbacks by providing added functionality.*

***Key Words***:  **IoT, Smart meter, Energy management, Home automation, Residential tariff, Demand Side management, Automatic Meter Reading.**

## 1. INTRODUCTION

India being a developing country, the energy demand is increasing by leaps and bounds. In order to meet with this rising energy demand, there has been a prolific increase in the implementation of alternative energy sources for generating more electricity, however, this is proving to be insufficient due to system energy loss. Therefore, a smart energy management system (SEMS) is necessary to ensure proper electrical power management, which will reduce the system energy losses. Furthermore, the integration of the SEMS with the internet enables the consumers to observe their consumption of electricity and take action according to their budget by remotely controlling the electrical equipment. It also provides a feasible mean to the electric suppliers for producing bills with minimal error.

With the advancement of technology, the accessibility of the internet is increasing day by day. Apart from being used for communication and entertainment purposes, the internet also provides a bunch of scopes in power system management, development, control, etc. Internet of things (IoT) is a cutting-edge technology that interconnects the 'things' over the internet [1]. These 'things' incorporate everything we can perceive of connecting-goods, buildings, appliances, machines, vehicles, plants, animals, and even human beings. It is estimated that the number of objects connected to the internet will reach 75 billion by 2025 [2]. IoT is a bidirectional approach, where objects export data to a distant server and the users can control the objects through the server by software programs and it is mainly done over Wi-Fi networks. The traditional electric power network has many limitations, however, by integrating with IoT it can be transformed into an intelligent power network [3]. The application of IoT can effectively improve the accuracy of real-time monitoring and control of smart grid [4, 5]. The information of power grid system can be sped up by utilizing IoT and thus is beneficial for effective management of the power grid infrastructure [6]. It can also be used for precise and accurate estimation of energy consumption [7]. Recent studies show that IoT can also be integrated with smart energy meters and can increase their accuracy [8-10]. IoT based smart energy meter has been proposed in [11-13]. However, it does not have the functionality of remotely controlling the home appliances. An efficient billing system can also be developed using IoT [14,15]. It also possesses great potentiality in its application in the control system of smart homes [16-18].

This paper proposes a SEMS based on IoT, which ensures the credibility of smart meter data as well as provides the facility for controlling home electrical appliances remotely. The energy usage data of the consumer is stored in NodeMCU, which is then transferred to a remote server on the internet using Wi-Fi. NodeMCU is an open-source development kit composed of micro-controller and ESP8266 Wi-Fi module, where micro-controller part does the necessary calculations and control and ESP8266 helps in communication over Wi-Fi.

The corresponding cost of the consumed electricity is automatically updated, reducing the errors that occur in the conventional energy meter system. This proposed method also reduces the complexity of bill payment and the consumer can check his/her energy usage at any time. Furthermore, it gives consumers the ability to remotely control any home appliance. Hardware implementation of the system along with necessary software configuration has been carried out in this research. Additionally, a comparative cost analysis with the existing energy meters available in the market has also been shown in this paper.

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The remaining part of the paper is organized as follows: in section II, the present condition of energy metering system in Bangladesh is represented. The tools and apparatus required for the proposed system and its working principle are discussed in section III. The problems that occur during the operation of the proposed smart energy meter and corresponding solutions are presented in section IV, which is followed by a cost analysis in section V. Finally, in section VI, the key features along with future scope are described as a conclusion.

## 2. PRESENT CONDITION OF ENERGY METERING SYSTEM IN INDIA

A common practice in India is that a person from utility services goes to individual consumers to collect the energy meter data. The bill is orderly prepared using those data and the bill paper, which contains all the information about the usage of electricity in that month, is sent to individual consumers for payment.

Finally, consumers pay their bill according to the bill paper, which was sent to them by going to a particular station or a bank. Therefore, this process is very much hassling and requires a lot of time and steps, and since there is direct involvement of human in collecting the meter data, the credibility of this system is compromised.

There are system losses occurring in the power network due to technical and non-technical aspects [19, 20]. Technical reasons include losses in power generation equipment, transmission lines, distribution lines, etc.; whereas non-technical losses occur mainly due to customer level meter tampering. In order to reduce the losses occurring at the customer level, the prepaid meter has been introduced in some cities and the rest are on the way.

Although the prepaid metering system offers more advantages than the conventional meter system, it also has some major drawbacks. The customers need to purchase a card to refill the account but purchasing the card is quite troublesome sometimes.

The consumers also need to predict the monthly bill and recharge accordingly, which can create a situation of uncertainty. Furthermore, prepaid energy meters do not provide the consumer with the ability to control electrical appliances remotely.

## 3. IoT BASED SMART ENERGY METER WITH HOME AUTOMATION

IoT based smart energy meter solves the issues of prepaid energy metering by minimizing the complexities and mitigates the non-technical losses by ensuring the credibility of data.

It also brings new important features, such as real-time viewing of consumption data and remote controlling of home appliances.

A single phase static watt-hour meter is used to calculate the consumed energy and these data are extracted from the meter through a LED. Table 1 shows the specification of the watt meter used in this paper.

**Table -1:** Specification of the Single Phase Static Watt hour Meter

| Supply System | Range |
|---|---|
| Voltage | 0 to 240V (Phase to neutral) |
| Current | 5A to 30 A |
| Frequency | 50Hz ± 5% |
| Temperature | −10°C to 50°C |

In order to perform IoT operation, a micro-controller along with Wi-Fi module is needed. The micro-controller sends the data to predefined internet server using Wi-Fi. NodeMCU is such a development board that provides combining the functionality of having both I/O ports like micro-controller and Wi-Fi module. This kit is based on the ESP8266 Wi-Fi module. It is programmed in an Arduino environment. Here, the micro-controller does all the calculations necessary, whereas ESP8266 provides the functionality of communication via Wi-Fi. The pin diagram of the NodeMCU is shown in Fig. 1.

PIN DEFINITION
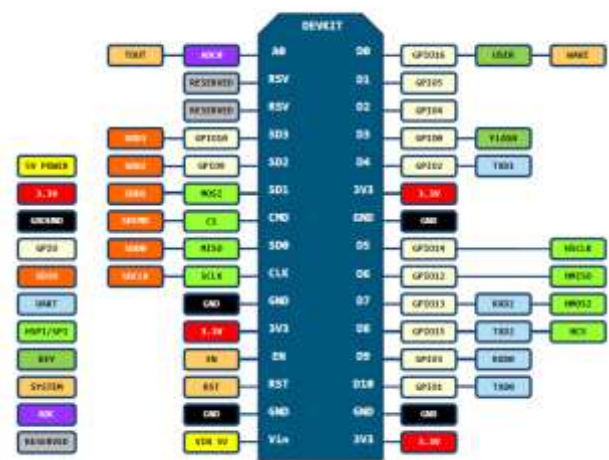


**Fig -1**: Pin diagram of NodeMCU.

Fig. 2 shows the functional block diagram of the whole system. In the functional block diagram of a conventional meter, only the ac power supply, energy meter, and loads block exist. However, some additional blocks are needed to be added here to realize the IoT and energy management features. The energy consumption data is taken from the energy meter. There is a LED in the energy meter named 'Cal', which blinks a certain fixed times per Kilo Watt Hour (kWh) for a particular energy meter. The meter used in this project has such a functionality, where the 'Cal' LED blinks 3200 times per kWh. This LED data is then fed to a micro controller. The number of blinking is observed by micro controller programming and by using this data, the total electricity units consumed and associated cost are calculated.
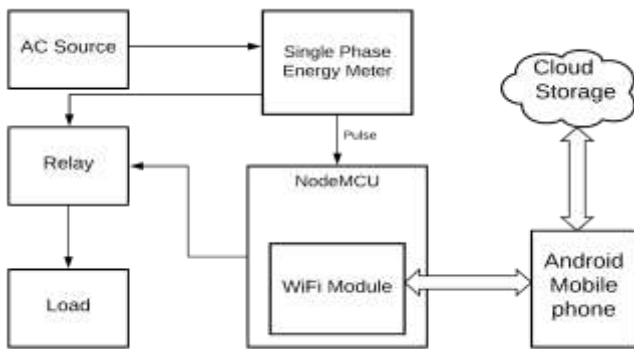
**Fig -2**: Block diagram of the IoT based smart energy management.

The main feature of this system is to collect data over the internet. Therefore, the consumed unit of electricity and associated cost data need to be transmitted over the internet. This is done by writing the required Arduino code in the NodeMCU. In order to practically implement this system, NodeMCU needs internet connectivity and to store data on the internet, hence, a database domain is needed. However, in this prototype, the website is hosted in cloud for storing information and Wi-Fi hot spot connection is given to the NodeMCU to simulate the prototype. The Wi-Fi service set identifier (SSID) and password are written in the Arduino script. Therefore, NodeMCU gets connected to local Wi-Fi whenever Wi-Fi is available. The updated data are transmitted at a certain time interval.

Another important feature of this system is the control of home appliances over the Internet. A user of this proposed system can check the status of his home appliances and can take any action as he wants; that means he can turn on or off any home appliance remotely using the internet. In order to simulate this, three LED's are connected to NodeMCU and can be controlled over the Internet. The loads are connected to the general purpose input/output (GPIO) pins. Some predefined commands have been configured in the Arduino script to make the LED either on or off. When those commands are transmitted to the NodeMCU from the application, the loads will respond according to the specified commands and thus, they can be controlled easily. In real life application, this feature can be implemented by using a relay circuit. By controlling the relay, electrical appliances like fan, light etc. can be turned on or off as required.

Power supply scenario across Indian regions should be made aware for the the people which is shown in Fig.4, that will be reduced to a reasonable amount by implementing this system.



**Fig -4:** Power Supply Scenario across Indian regions

When a user installed the android application he/she is required to login to the application via their facebook account. After logged in to the application the user will view the appliance control options and an IP bar for connecting with the NodeMCU. The sidebar menu shows various tabs namely statistics, cost estimation and logout option. In the statistics tab, it shows the overall energy consumption and energy consumed by individual devices.

The user is allowed to enter the details of the device by pressing the Details button which store the entered information in secure database in the cloud. The cost estimation tab shows the overall cost of energy consumption according to the regional tariff rate in Rupees/kWh which are shown in Fig.3.
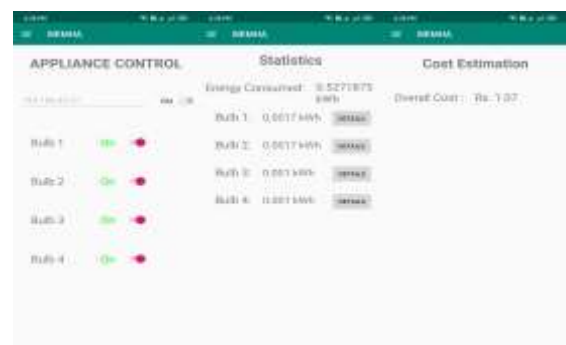


(a)        (b)        (c)

**Fig -3**: Application showing the a)Home Automation, b)Energy Consumption, c)Cost Estimation.

The existing tariff rates in Tamil Nadu, India for different categories according to TNERC (Tamil Nadu Electricity Regulatory Commission) is shown in Fig.5.



**Fig -5:** Existing tariff rates in Tamil Nadu, India.

## 4. PROBLEMS AND SOLUTION

NodeMCU needs power from the main supply to operate; thus when power interruptions occur, it will be turned off. However, there is no possibility of data loss as the data is stored periodically in the internal memory of the NodeMCU. Each time the NodeMCU starts, it extracts the most recently updated data from the memory. This system needs an Internet connection to send data to the web server and there might be the possibility of having no internet connection at a certain time. However, this problem is solved as NodeMCU sends the updated data whenever it regains internet connectivity. Data are always updated and stored in the internal memory of NodeMCU and is sent to the server whenever the internet is available. Therefore, there is no possibility of data loss. The exchange of data over the public domain such as the Internet is very much susceptible to unauthorized access [22]. Therefore, the system will be synchronized to a distant server and it can be programmed so that any undesirable attempt will inform the consumer as well as the electricity provider. In this way, the risk of data theft can be reduced to a minimum.

## 5. COST ANALYSIS

Cost of different equipment required for the proposed system and the overall cost is shown in Table 2. In our proposed design we used the Universal Single Phase Energy Meter which is a conventional energy meter. Additional equipment such as, NodeMCU and Relay module are used as add-ons so that this conventional energy meter can function as IoT based smart energy meter. Furthermore, it has the facility to provide the consumers the ability to control their home appliance remotely. The aforementioned add-ons are also compatible with the existing prepaid meters available in the market. Therefore, the consumers are able to pay their bills without having to predict their monthly consumption of electricity with the added facility of remotely controlling their home appliance. From data presented in Table 2, it can be said as the add-ons cost is very cheap, therefore, it is very much cost-effective integrate them with conventional or prepaid energy meters.

**Table -2:** COSTING OF DIFFERENT EQUIPMENT S OF THE WIRELESS ENERGY METER WITH HOME AUTOMATION

| Equipment | | Market Price |
|---|---|---|
| Universal Single Phase Energy Meter | | INR 450 |
| Add-ons | NodeMCU | INR 350 |
| | Relay Module | INR 480 |
| | Extras(jumpers,bread boards,etc,.) | INR 150 |
| **Total** | | **INR 1430** |

## 6. CONCLUSIONS

In this paper, integration of IoT with energy management system has been demonstrated to make a more effective and reliable system compared with the conventional energy management system. The NodeMCU used in this system has the dual functionality of a micro-controller and a Wi-Fi module, which eliminates the need for an additional micro-controller. Furthermore, remote control of domestic appliances has also been made possible through this system. The total hardware implementation along with interfacing with the internet has been presented in detail. For ensuring the cost effectiveness, a detailed cost analysis has been conducted. The overall cost of the proposed IoT based smart energy management system is INR 1430 and add-ons cost is INR 980. Hence, the proposed system is cost effective and the add-ons can be also integrated with the existing prepaid meters, which can expunge its major drawbacks by providing added functionality. Therefore, the presented design in this paper, possesses high potentiality in its application in energy metering system of India.

## 7. FUTURE ENHANCEMENT

The proposed system can be further enhanced by implementing a separate cloud server connecting the power utility and the user residence for automated bill payment and information storage. The android application can be improved with more security and versatility like adding bank account information, complaint filing, etc., and it can integrated with accessories for various kind of devices like for example air-conditioners and washing machines have various options and those can be embedded into the application.

## REFERENCES

[1]  S. N. Han, I. Khan, G. Myoung, N. Crespi, and R. H. Glitho, "Computer Standards & Interfaces Service composition for IP smart object using realtime Web protocols : Concept and research challenges," Comput. Stand. Interfaces, vol. 43, pp. 79–90, 2016.

[2]  M. Swan, "Sensor Mania! The Internet of Things, Wearable Computing, Objective Metrics, and the Quantified Self 2.0," J. Sens. Actuator Networks, vol. 1, pp. 217–253, 2012.

[3]  G. Bedi, G. K. Venayagamoorthy, R. Singh, R. R Brooks, and K. C. Wang, "Review of Internet of Things (IoT) in Electric Power and Energy Systems," IEEE Internet of Things Journal, vol. 5, pp. 847-870, 2018.

[4]  L. Li, H. Xiaoguang, C. Ke and H. Ketai, "The applications of WiFi-based Wireless Sensor Network in Internet of Things and Smart Grid," 6th IEEE Conference on Industrial Electronics and Applications, pp. 789-793, 2011.

[5]  Miao Yun and Bu Yuxin, "Research on the architecture and key technology of Internet of Things (IoT) applied on smart grid," International Conference on Advances in Energy Engineering, pp. 69-72, 2010.

[6] Q. Ou, Y. Zhen, X. Li, Y. Zhang, and L. Zeng, "Application of internet of things in smart grid power transmission," FTRA International Conference on Mobile, Ubiquitous, and Intelligent Computing, pp. 96-100, 2012.

[7] F. Englert, P. Lieser, A. Alhamoud, D. Boehnstedt and R. Steinmetz, "Electricity-Metering in a Connected World: Virtual Sensors for Estimating the Electricity Consumption of IoT Appliances," 3rd International Conference on Future Internet of Things and Cloud, pp.317-324, 2015.

[8] D. Alahakoon, and X. Yu, "Smart Electricity Meter Data Intelligence for Future Energy Systems: A Survey," IEEE Transactions on Industrial Informatics, vol. 12, pp. 425-436, 2016.

[9] P. D. Talwar, and S. B. Kulkarni, "IoT Based Energy Meter Reading" International Journal of Recent Trends in Engineering & Research (IJRTER), vol. 2, pp. 586-591, 2016.

[10] E. Hossain, J. Hossain and F. Un-Noor, "Utility Grid: Present Challenges and Their Potential Solutions," IEEE Access, vol. 6, pp.60294-60317, 2018.

[11] F. Abate, M. Carratù,C. Liguori , M. Ferro, and V. Paciello, "Smart meter for the IoT," IEEE International Instrumentation and Measurement Technology Conference (I2MTC), pp. 1-6, 2018.

[12] B. Sahani, T. Ravi, A. Tamboli, and R. Pisal, "IoT Based Smart Energy Meter," International Research Journal of Engineering and Technology (IRJET), vol. 4, pp. 96-102, 2017.

[13] A. Singh, and R. Gupta, "IoT based smart energy meter," International Journal of Advance Research and Development, vol. 3, pp. 328-332,2018.

[14] P. Mahajan, S. Tatia, and P. Jadhav, "Smart Meter: An IOT Based Smart Meter for Live Electricity Monitoring and Bill Payment," International Journal of Electrical, Electronics and Computer Systems (IJEECS), vol. 5, pp. 49-51.

[15] N. N. Sasane, N. S. Sakat, K. N. Shital, V. R. Kaushik, and P. K. Pallav, "IOT based energy meter billing and monitoring system - A case study," International Research Journal of Advanced Engineering and Science, vol. 2, pp. 64-68, 2017.

[16] S. Chen, C. Lai, Y. Huang, and Y. L. Jeng, "Intelligent home-appliance recognition over IoT cloud network," 9th International Wireless Communications and Mobile Computing Conference (IWCMC), pp.639-643, 2013.

[17] W. T. Cho, Ying-Xun Lai1, C. F. Lai, and Y. M. Huang, "Appliance-Aware Activity Recognition Mechanism for IoT Energy Management System," The Computer Journal, vol. 56, pp. 1020-1033, 2013.

[18] M. Wang, G. Zhang, C. Zhang, J. Zhang and C. Li, "An IoT-based appliance control system for smart homes," Fourth International Conference on Intelligent Control and Information Processing (ICICIP), pp. 744-747, 2013.

[19] F. I. Bappy, M. J. Islam, A. K. Podder, D. R. Dipta, H. M. R. Faruque, and, E. Hossain, "Comparison of Different Hybrid Renewable Energy Systems With Optimized PV Configuration to Realize the Effects of Multiple Schemes," 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT), in press.

[20] E. Hossain, I. Khan, F. Un-Noor, S. S. Sikander, and M. S. H. Sunny, "Application of Big Data and Machine Learning in Smart Grid, and Associated Security Concerns: A Review," IEEE Access, vol. 7, pp.13960-13988, 2019.

[21] Tariff Rate. [online] Available at: https://www.tangedco.gov.in/linkpdf/ONE_PAGE_STATEMENT.pdf.

[22] M. S. Rahman, M. S. Hossain, E. H. Rahat, D. R. Dipta, H. M. R. Faruque, and F. K. Fattah, "Efficient Hardware Implementation of 256-bit ECC Processor Over Prime Field," International Conference on Electrical, Computer and Communication Engineering (ECCE), pp. 1-6, 2019.